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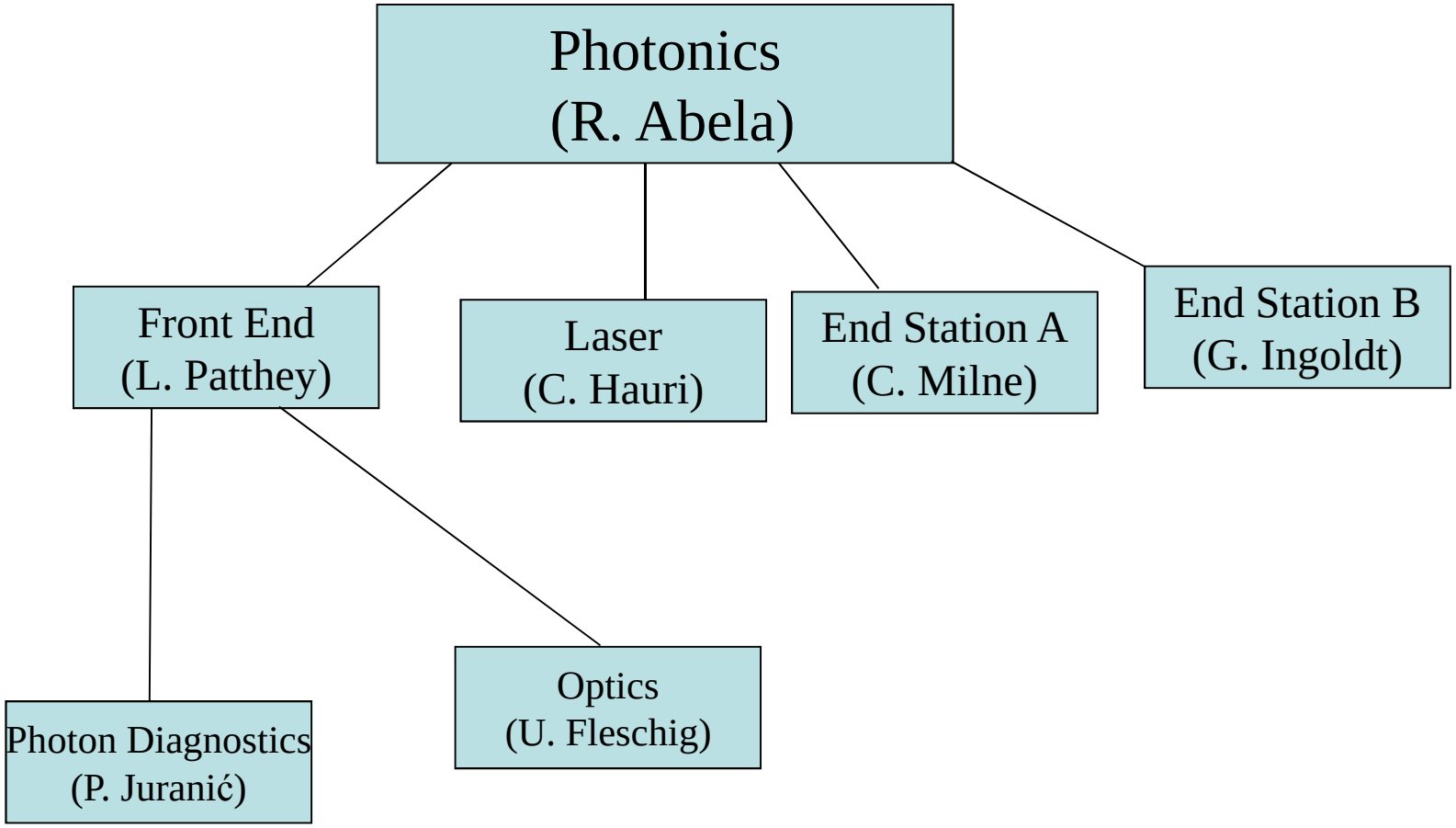
SwissFEL Photon Beam Diagnostics Concepts

Outline

- Introduction
- Photon beam intensity and position monitors
  - Gas-based
  - Diode and back-scattering
- High resolution grating spectrometer
- THz Streak Camera
- Destructive monitors
  - Beam profile monitor
  - Spontaneous radiation monitor
- Layout
- Acknowledgment and Conclusion

Introduction



Requested Specifications

Diagnostic	Wavelength Range	Precision	Dynamic Range (Pulse Energy)	Feedback	Absolute/ relative	Priority	Photon Diagnostic	
Pulse Energy	all	1% (≈5%)	10 µJ-10 mJ	yes	relative	1	Gas Beam Intensity monitor (PBIM)	ND
Pulse Energy	all	1%	1 nJ*- 10 mJ	no	absolute	1	Photon Beam Position Monitor (PBPS)	ND (>4KeV)
Photon Energy	all	1e-4 (1e-3 for less than 4 keV)**	10 µJ-10 mJ	yes	relative	1	Low Energy Res. Spectrometer (PSPL)	ND
Photon Energy	all	1e-4 (1e-3 for less than 4 keV)**	1 nJ-10 mJ	no	absolute	1	High Energy Res. Spectrometer (PSPH)	ND (>4KeV)
Transverse Position	all	10 micron	10 µJ-10 mJ	yes	relative	1	Gas and Solid Beam Position monitor (PBPG) and (PBPS)	ND
Transverse Intensity Distribution	all	10 micron	1 nJ-10 mJ	no	absolute	1	Photon Beam Profile Monitor (PPRM)	D
Monochromator	> 4 keV	<1e-4	-	no	absolute	1	Double Crystal Monochromator at AR2	ND
Pulse Length	all	0.5 fs	10 µJ-10 mJ	no	absolute	1	Gas Time Arrival Monitor (PTAG)	ND
FEL Bandwidth	all	1.00E-04	10 µJ-10 mJ	no	relative	2	Low Res. Spectrometer (PSPL)	ND
High-res Spectrometer	~8-12 keV	<1e-5	10 µJ-10 mJ	no	absolute	2	Double Crystal Monochromator (ODCM) and 2D detector for spontaneous Radiation (PSRD)	ND
Collimation	all	10 microns	-	-	-	2	--	
Longitudinal Profile	all	0.5 fs	10 µJ-10 mJ	no	absolute	3	--	
Coherence	12 keV	5%	1 nJ-10 mJ	no	absolute	3	--	

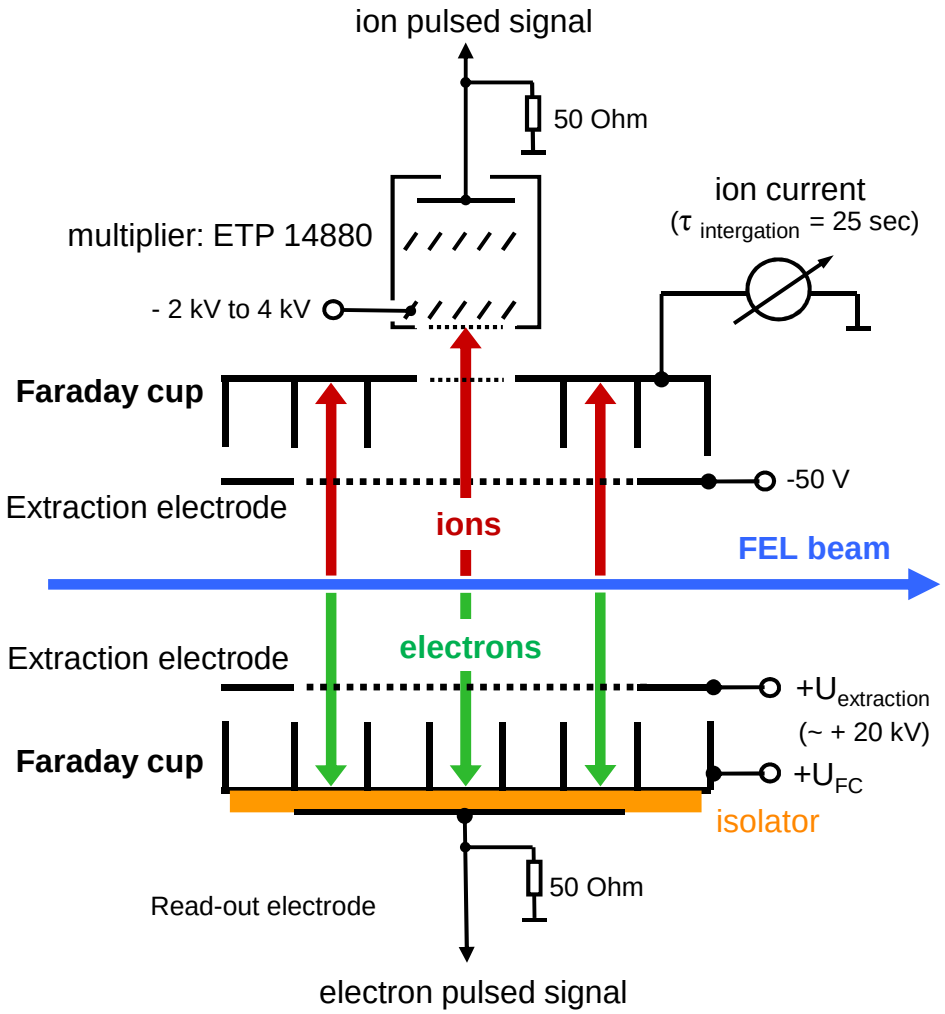
* with direct beam on diode mounted on Photon Beam Profile Monitor (PPRM)

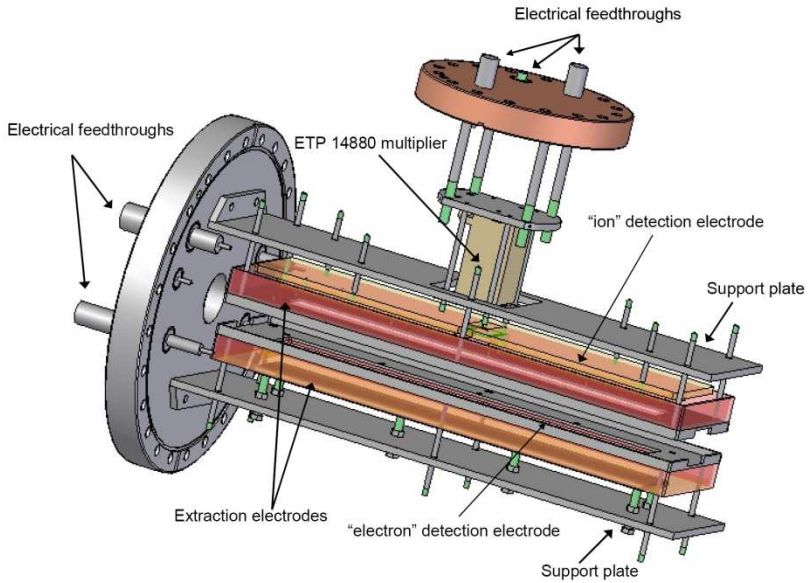
** with Gas Time Arrival Monitor (PTAG), more study are need for energy resolution requement

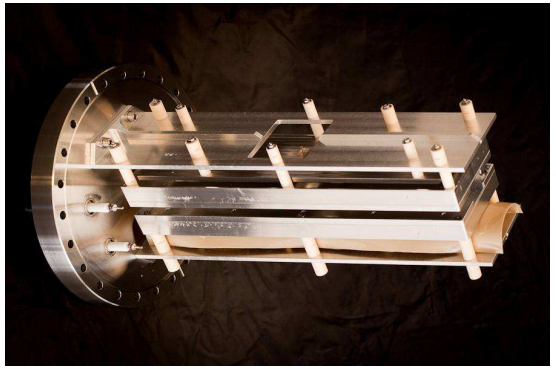
Photon Beam Intensity and Position Monitors

- Need to cover intensity range from spontaneous radiation to full SASE.
- Need absolute and relative measurements.
- Need to be non-destructive for the SASE beam.
- A multi-part approach:
  - Direct diode detectors for relative spontaneous radiation measurements.
  - Backscattering and gas-based detectors for relative intensity measurements.
  - Gas based detectors for absolute intensity measurements.
  - Gas and backscattering detectors for position measurements.
- Lots of similarities with the XFEL system, but few key differences.
- We are counting on collaboration and further work with Kai Tiedtke's group for some of these devices.

XGMD from DESY/XFEL







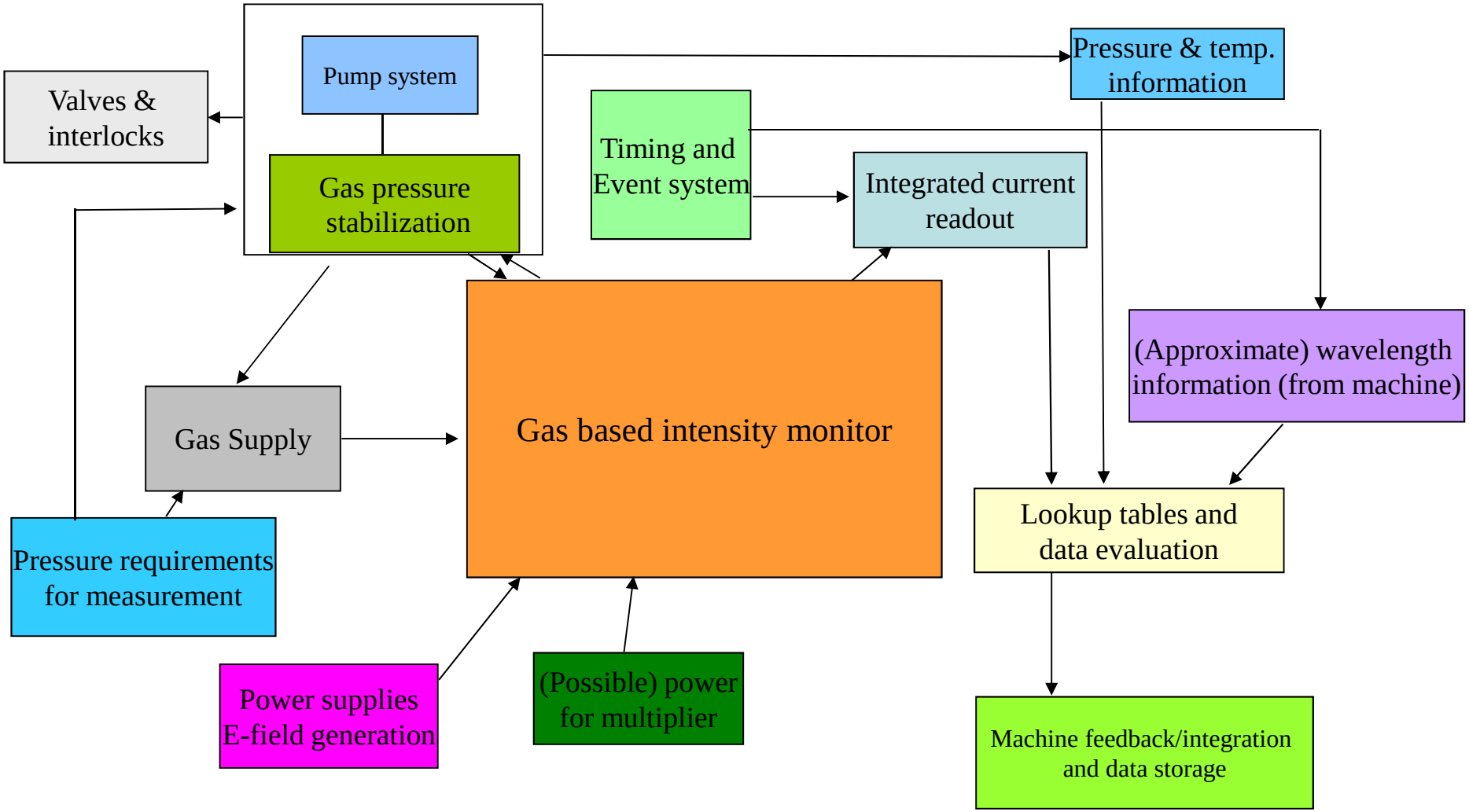
High extraction voltage of up to 20 kV – 30 kV may have to be applied to prevent detection of highly energetic photoelectrons by the ion detector.

Courtesy of Kai Tiedtke

XGMD requirements for SwissFEL

- Photon energy range: 2 to 12.4 keV
- Number of pulses per second: 100
- Relative signal measurement and evaluation time: < 2 ms per pulse (for feedback)
- Relative uncertainty (pulse to pulse): < 1 % (for more than 10^{10} photon per pulse)
- Absolute signal evaluation time: seconds (no feedback).
- Absolute uncertainty for the pulse energy: <10 %
- Operating pressure: 10^{-6} mbar – 10^{-4} mbar
- Needs to be EPICS compatible
- Combined with the gas-based position monitor?

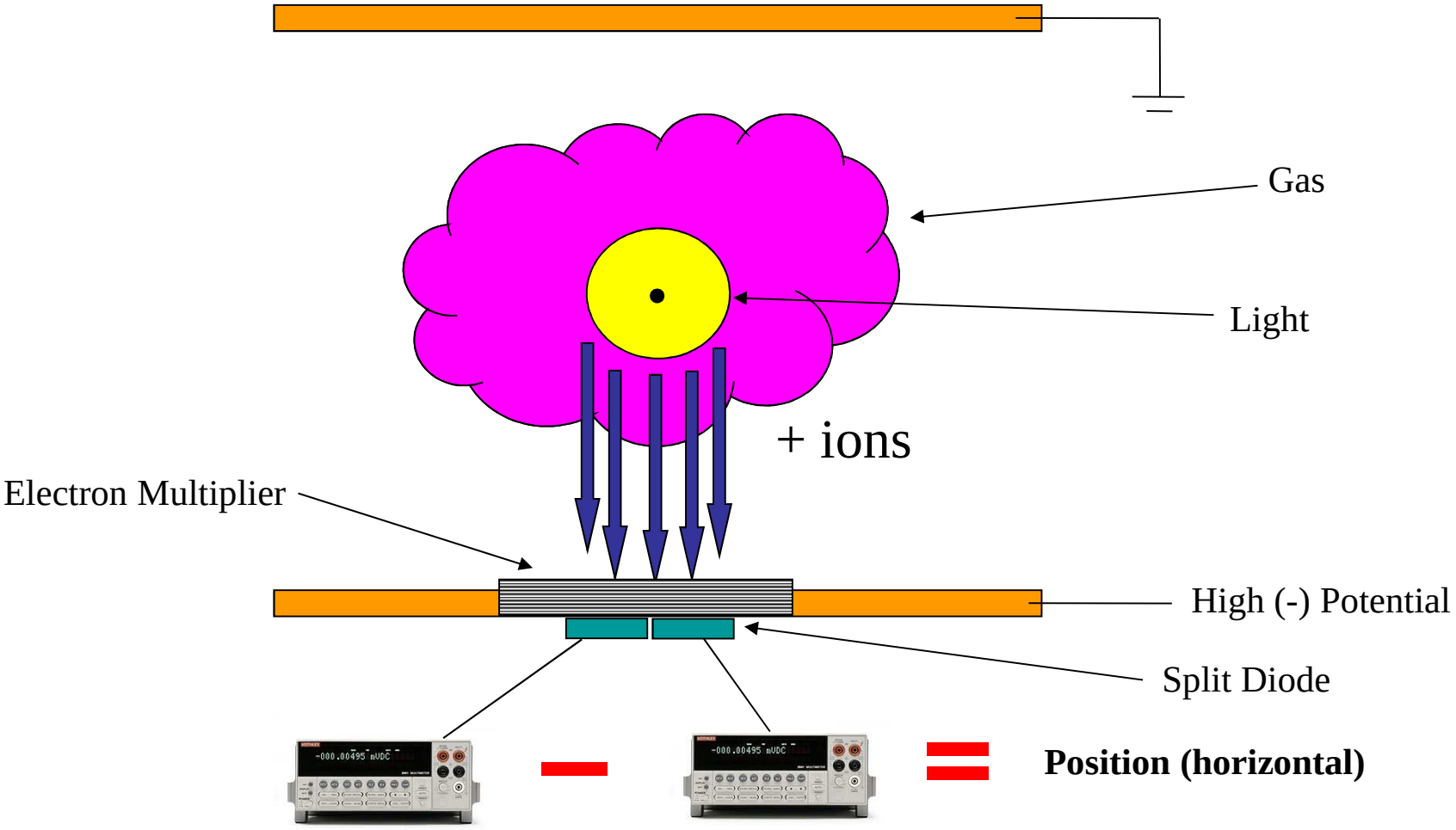
Intensity monitor schematic summary



All at 100 Hz (several milliseconds per pulse)!

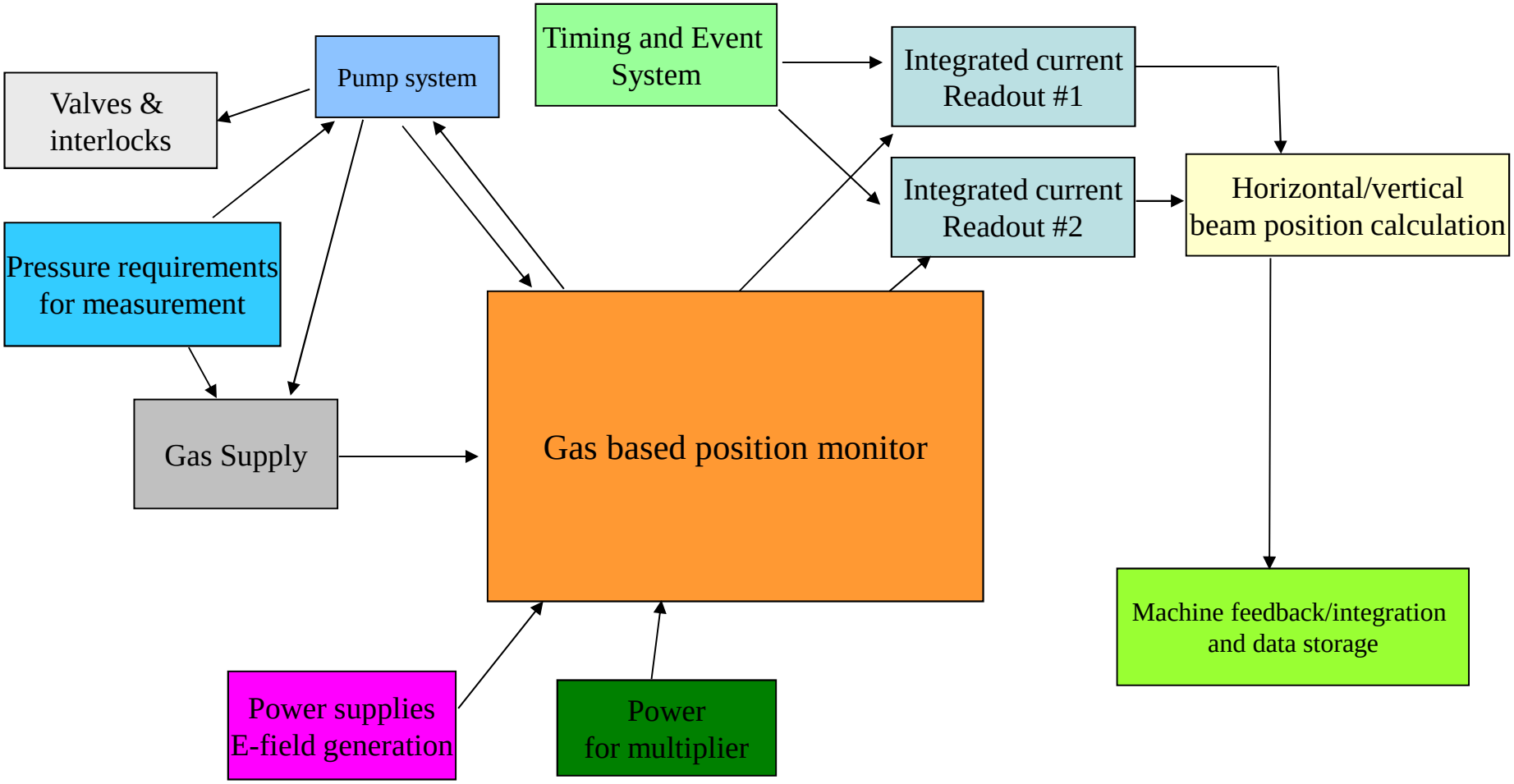
Gas split diode position monitor

Needs 10 micromter accuracy



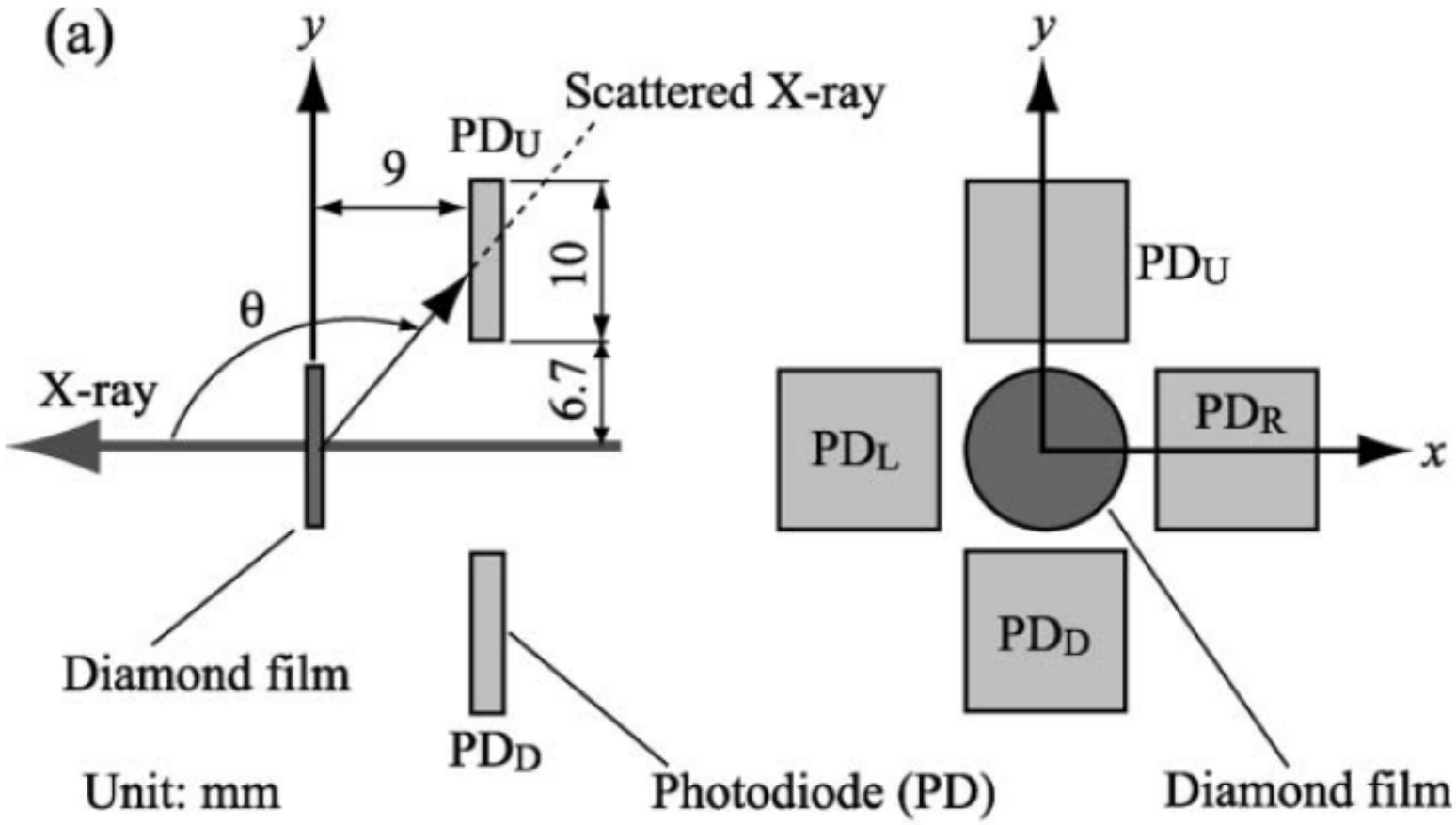
Works for all photon energies!

Position monitor schematic summary



All at 100 Hz (several milliseconds per pulse)!

Diode and back-scattering monitors

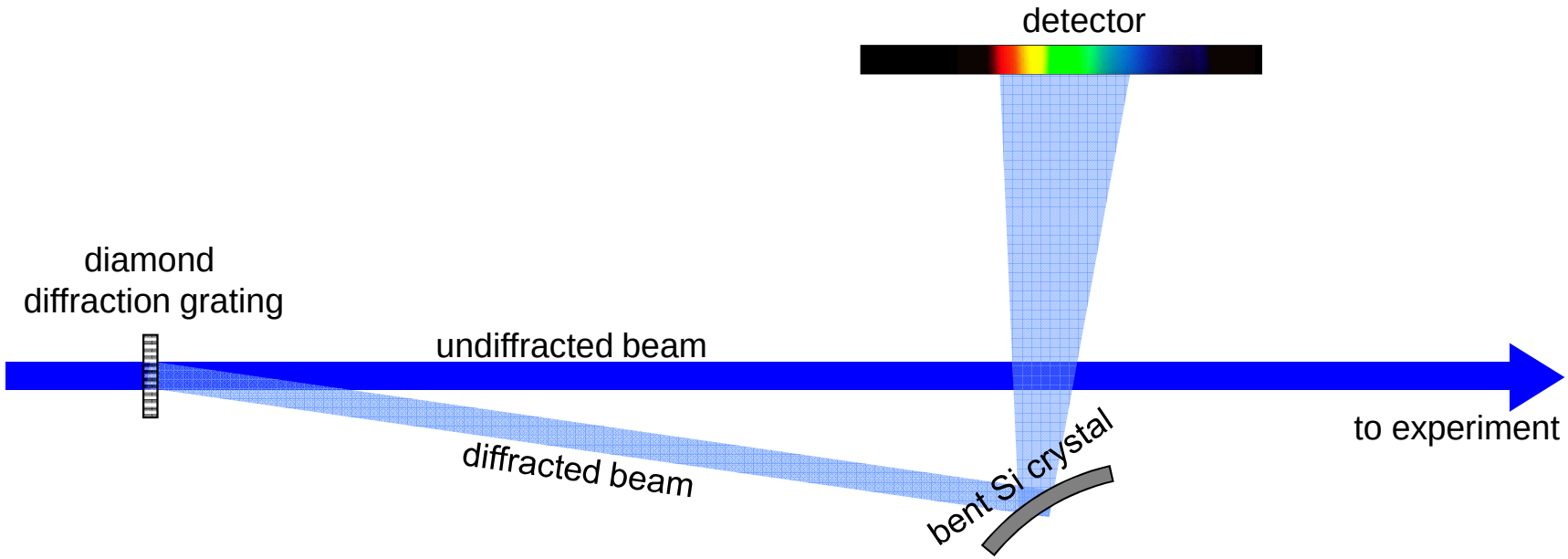


Tono *et al.*, Rev. Sci. Inst. **82**, 023108(2011)

Diode and back-scattering monitors

- Similar to the SACLA setup
- Diode for low intensity light, directly in beam (destructive)
- Back-scattering for high intensity light
- Only relative measurements for intensity
- Absolute position accuracy to 10 micrometers.
- Back-scattering only useful above 4 keV photon energy due to thickness of film
- Quality of film an issue
- Will need to be calibrated against the gas-based detectors to ensure diodes have not degraded

Bent grating spectrometer

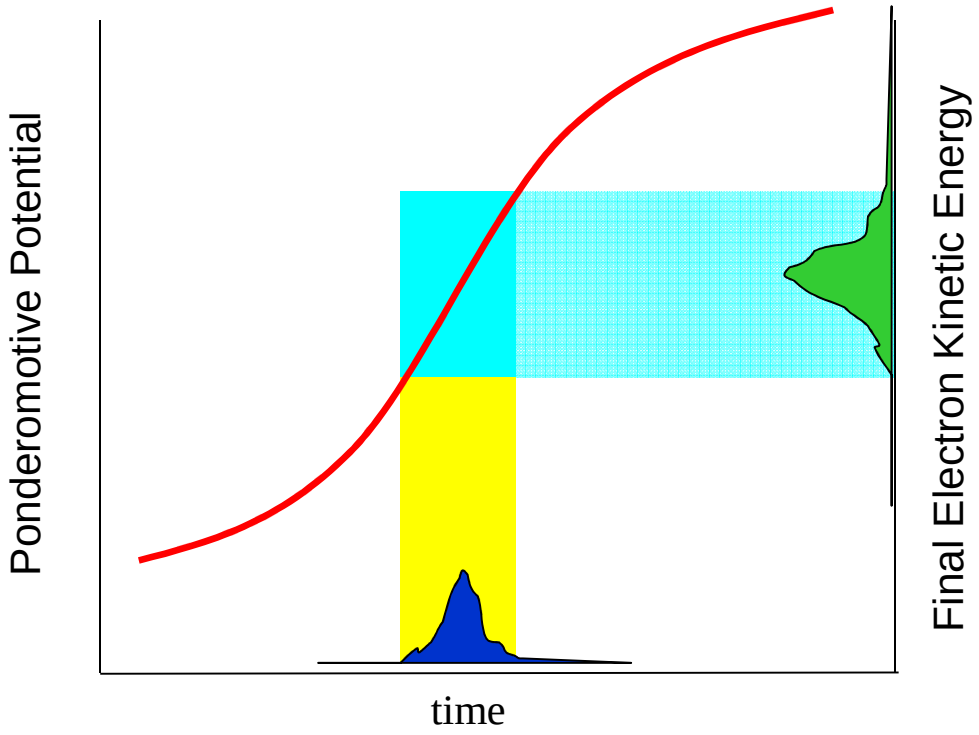


Courtesy of Christian David

Bent grating spectrometer

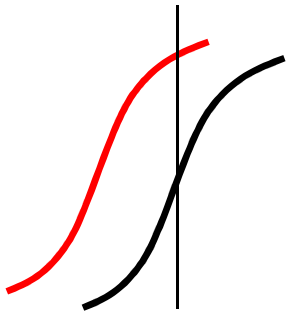
- Resolution of 10^{-4} or better, depending on the crystal—meets the requirements
- Can be used above 4 keV photon energy
- The Gotthard microstrip detector can be easily integrated with PSI infrastructure
- PSI expertise for development and building of all components
- The concept has been tested and works
- Possible collaboration and cooperation with the XFEL project
- Under development

THz Streak Camera: theory



- Needs either high fields or fast field rise times for good resolution
- Hard to meet criteria and still have a good dynamic range for jitter

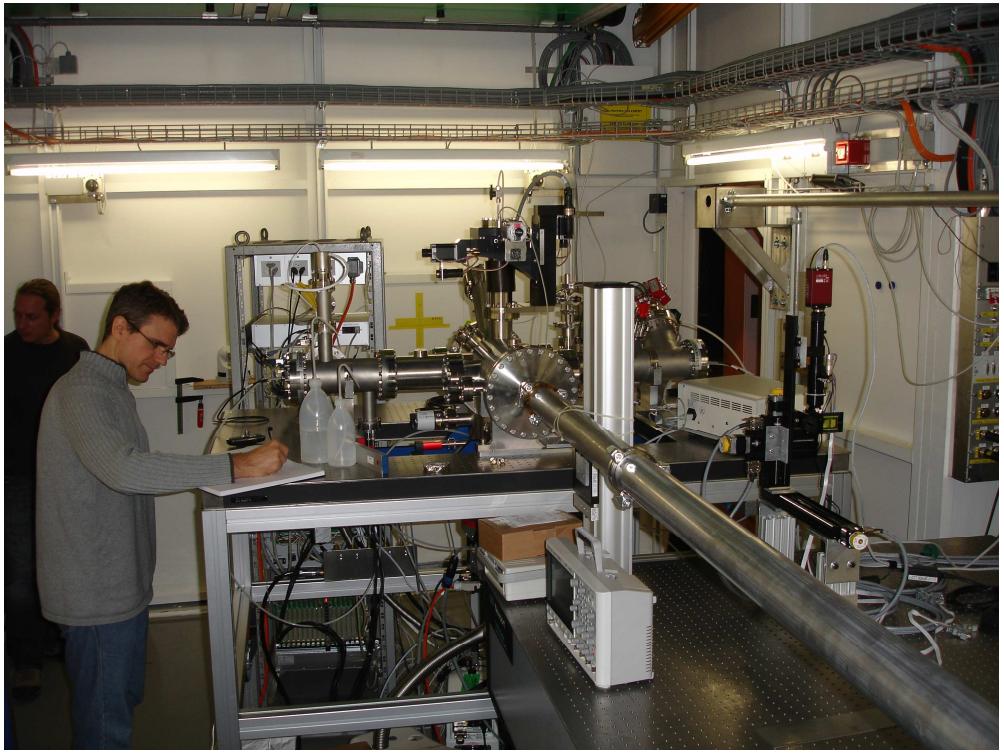
THz Streak Camera: hybrid concept



One setup always in the linear region

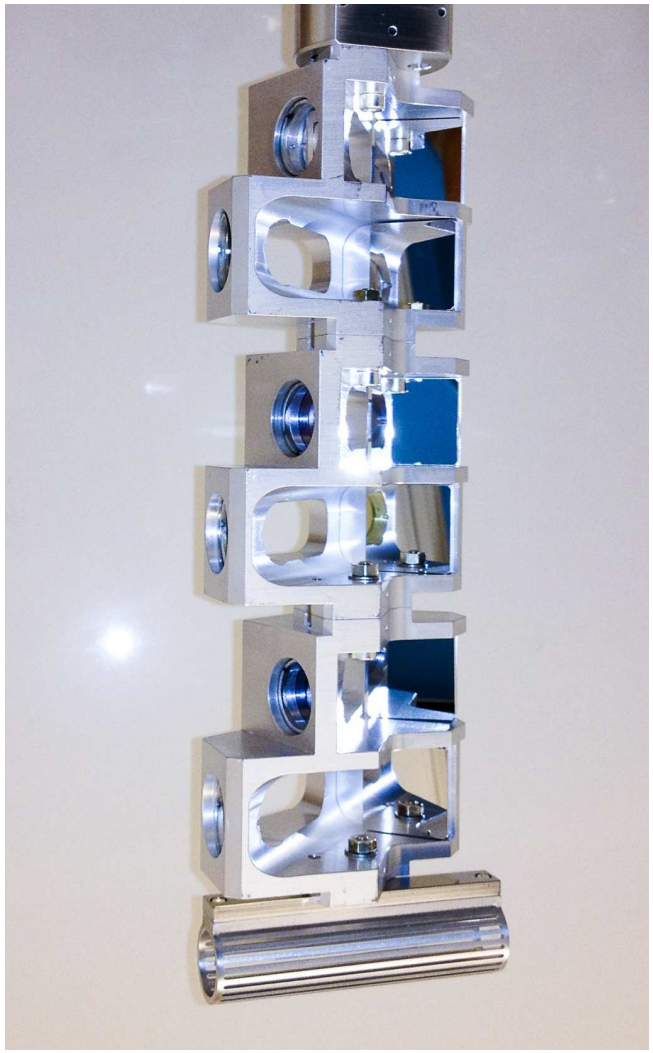
"Rough" timing to find our time window

THz Streak Camera: status



- Chamber assembled and equipment tested (thanks Jens!)
- Waiting on laser to start tests (should be any day now)
- Tests at PSI with HHG, later a test at SACLA
- Hopefully lots of collaborations with other institutes

Destructive Monitors: screen solution



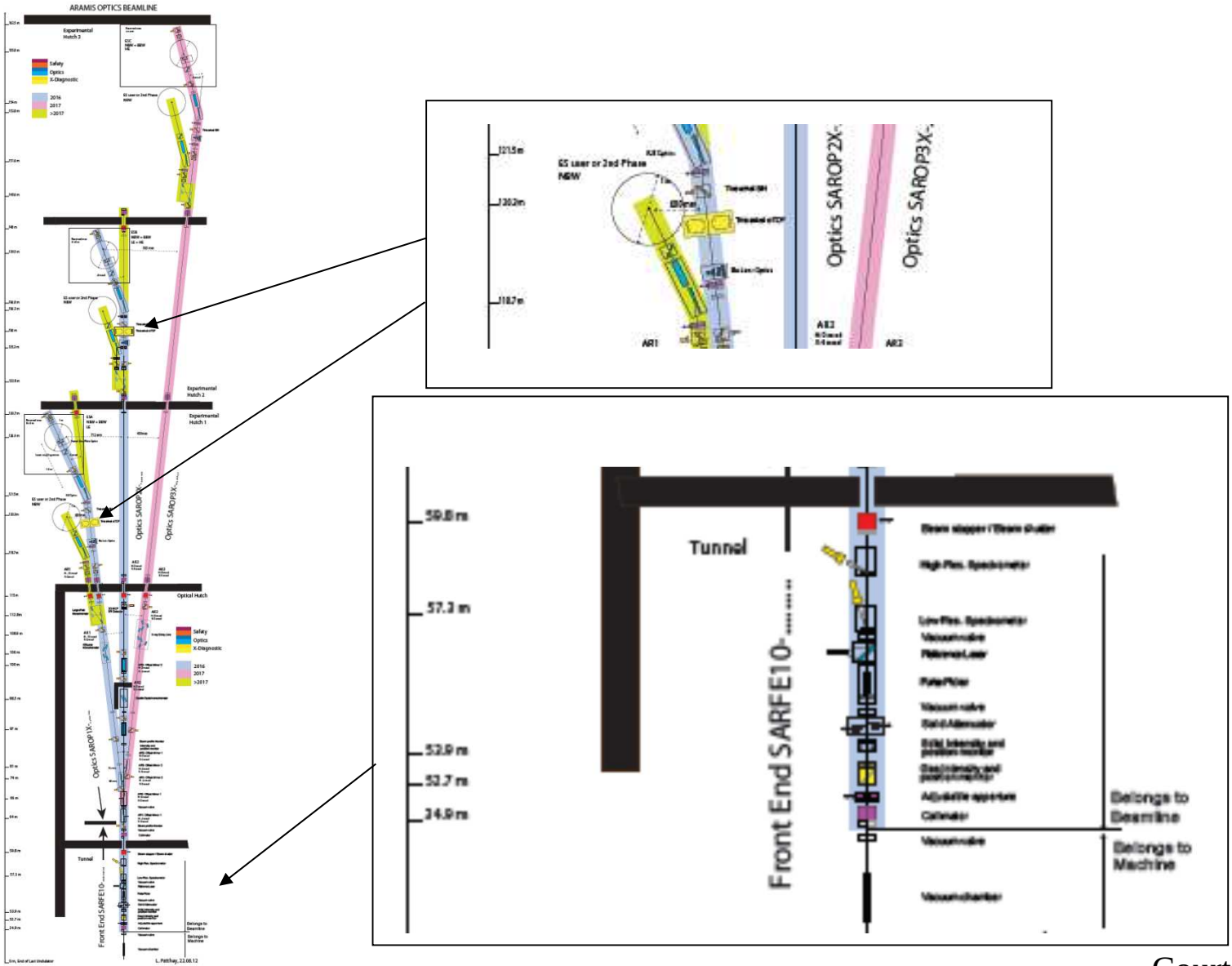
Courtesy of Rasmus Ischebeck

Courtesy of Luc Patthey (SACLA screen)

Destructive Monitors

- Yag screens, a mirror, and a camera look at the beam profile and beam alignment destructively
- An addition of an MCP can expand the use of the screens for spontaneous radiation measurements
- Need high-resolution cameras
- Most screens will be for checking alignment only—no need for fast cameras.
- Some will be made with fast cameras, for commissioning and machine use.
- 2D image analysis software will also be needed—such software exists already for EPICS at PSI

Layout



Courtesy of Luc Patthey

Acknowledgments and Conclusions

Many thanks to the staff at PSI, most of all to:
The Laser group, led by Christoph Hauri;
The Vacuum group, including Peter Huber, Gaiffi Nazareno, and Lothar Schultz;
The Electronics group, led by Patrick Pollet;
The technicians, in particular Beat Rippstein;
The Controls group, particularly Elke Zimoch, Dirk Zimoch, and Timo Korheren;
Niklaus Schlumpf, Rasmus Ischebeck, Volker Schlott, Peter Wiegand, Luc Patthey,
Christian David (and his group), and Rafael Abela,
Outside of PSI: Kai Tiedtke (and his team), Jan Gruenert (and his team, especially Jens Buck),
Makina Yabashi (and his team),
LCLS staff, and all of the other collaborators around the world.
Along with all the others who are helping and supporting these projects and SwissFEL.

The future:
First write the work packages, defining the work and resources, hopefully by mid-year.
Then we get the resources and do the work!
Deadline for fully-functioning units is late 2015, early 2016, when the front end starts being built.


SINQ